EPIDEMIOLOGICAL STUDY OF FOLIAR BLIGHT OF WHEAT

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ABSTRACT

Foliar blight is one of the major biotic stresses of wheat. Study conducted to ascertain the effect of biological and meteorological factors on disease development under timely to late seeding conditions revealed that late seeded crop is more vulnerable to foliar blight development than timely seeded. PDI and AUDPC of late seeded crops exhibited significantly strong positive correlation with crop age i.e. days after sowing. The PDI and AUDPC were found accelerated with advancement of crop age. The meteorological factors *viz.*, minimum, maximum, mean, morning and afternoon temperatures showed significant positive correlation, whereas morning, afternoon and mean relative humidity reflected significantly negative correlation with PDI and AUDPC. Significant effects were included in a regression model. The co-efficient of determination (R^2) for the fitted model inclusive of only two factors *viz.*, crop age (i.e. DAS) and cumulative degree days for disease intensity and AUDPC were 0.77 and 0.78, respectively.

KEY WORDS: Disease, epidemiology, Foliar blight, *T. durum*,

INTRODUCTION

Foliar blight disease is one of the major biotic constraints to wheat in warmer regions. *Bipolaris sorokiniana* (sacc.) Shoemaker [Syn. *Helminthosporium sativum* P.K.B. *Drechslera sorokiniana* (Sacc.) Subram. and Jain; Teliomorph : *Cochliobolus sativus* (Ito and Kuribayashi) Dresch. Ex Dastur], an aerial pathogen causes foliar blight of wheat. Numerous reports have stressed the importance of *Helminthosporium* leaf blight as major biotic constraint to growing wheat in warmer areas (da Luz and Bergstrom, 1987; Hetzler *et al.*, 1991; Dubin and van Ginkel, 1991; Duveiller and Gilchrist, 1994; Dubin *et al.*, 1998; Saari, 1998). Crop growth stage and weather in particular high temperatures and humidity favouring long duration of leaf wetness are considered to be associated with foliar blight development (Nema and Joshi, 1973, da Luz and Bergstrom, 1986, Reis, 1991, Sentelhas *et al.*, 1993). Yield losses are significant and vary depending on sowing time, year, location and stress conditions. Hence, our goal was to develop a simple model that could be used to predict the disease development in order to improve the disease management. Development of a predictive model as a part of forecasting system is necessary; therefore, fungicide applications can be timed more accurately. Determination of a quantitative relationship between the environmental factors such as temperature, relative humidity and crop age with foliar blight severity is critical in the development of such a model. Therefore, this study was undertaken to determine the effects of temperature, relative humidity, plant age on development of foliar blight of wheat.

MATERIALS AND METHODS

Experiment site

The present study was conducted under winter conditions characterized by the absence of significant rainfall during the wheat growing season. The experiment was conducted at Wheat Research Station, S.D. Agricultural University, Vijapur, Gujarat during the nine consecutive (1998-99 to 2006-07) wheat growing season. The Wheat Research Station, Vijapur is located between 23^0 35' N and 72^0 58' E and 125.8 m above mean sea level. The soil of the experimental site is deep in depth and classified as inceptisols with alluvial sandy to sandy loam surface texture. The climatic conditions of the area represent the tropical conditions with semi-arid climate. Site is characterized under North Gujarat Agro-climatic Zone-IV on the basis of rainfall pattern.

Experiment management

The field experiment was laid out in a randomized block design with four replicates. A durum genotype GW 1156 - highly susceptible to foliar blight disease was seeded from 15 November to 25 December at ten days intervals. The optimum seeding time in the region ranges from 15 to 25 November. Individual experimental plot was 5.0 x 2.76 m in area and consisted of twelve rows with 23 cm spacing, sown using the standard seed rate of 150 kgha^{-1}. Recommended dose of fertilizer (120 N : 60 P_2O_5 : 00 K_2O kgha^{-1}) was applied and seven irrigations were given as required for a successful wheat crop. Plots were kept free from weeds by hand weeding.

Disease assessment

Disease severity was assessed by using 0-9 scale (Saari and Prescott, 1975). Twenty five plants per plot were selected randomly and tagged for scoring disease intensity from disease initiation to crop maturity at ten days interval. Per cent Disease Intensity (PDI) was calculated as per Mckinney (1923). The Area Under Disease Progress Curve (AUDPC) was calculated using the formula outlined by Shanner and Finney (1977).

Meteorological data

Data of different weather variables such as maximum, minimum, morning and afternoon temperatures, morning and afternoon relative humidity, duration of sunshine hours were obtained from meteorological observatory located at the station and data were averaged for the D-10 (i.e. average of 10 days before respective observation) period from disease initiation to maturity of the crop. The value of Degree Days (i.e. Thermal time) per assessment period was calculated as the sum of daily mean temperature (^{o}C) minus base temperature (10 ^{o}C) (Magboul *et al.*, 1992), where the pathogen activity ceased.

Data analyses

Per cent disease intensity (PDI), AUDPC, weather variables and degree days were subjected to correlation and multiple regression analyses with weather factors to determine the relationship between biological and meteorological variables and disease development under natural conditions. The prediction equation used was $Y=a+b_1x_1+b_2x_2\ldots\ldots\ldots\ldots+b_{10}x_{10}$, where Y=predictive disease intensity, a= intercept, b_1 to b_{10} = partial regression co-efficient and x_1 to x_{10} = variables.

RESULTS AND DISCUSSION

Year-wise Disease Scenario

The disease development was quite satisfactory in all the sowing dates during 1998-99 to 2003-04 except 2000-01. Out of nine years, during last three years i.e. 2004-05, 2005-06 and 2006-07, disease was not appeared. Therefore, first six years results were utilized for statistical analyses and compared the variables with remaining years for valid inferences.

Crop age-wise Disease Development

The results of disease intensity (PDI) at various crop ages are depicted in Table 1. The seeding date was found significantly influencing the disease development from early growth phase (31-40 DAS) to hard dough phase (71-80 DAS) during the years as well as in pooled data. At terminal phase, it was found non-significant. It is very perspicuous from the data that development of disease was faster in early crop growth phases under late seeded crop i.e. after 5 December in comparison to timely seeded, which reflects that late seeded crop is more vulnerable in its early growth phases than timely seeded. However, the disease development in timely seeded conditions was found more in advance growth stages which might be the effect of higher temperatures and development of endogenous inoculums pressure in crop vicinity.

Relationships

(a) Crop age (days after sowing) with disease intensity and AUDPC:

(i) Seeding Date-Wise : Correlation analysis of disease intensity and area under disease progress curve with biological factor i.e. crop age at different seeding dates (Table 2) indicated that per cent disease intensity and area under disease progress curve i.e. disease progression had significant positive correlation with crop age (DAS). The disease intensity and area under disease progress curve of late seeded crops manifested very strong positive correlation with correlation co-efficient of 0.89862, 0.91056 and 0.91397 and 0.85686, 0.92549 and 0.85501, respectively than timely seeded. This implies that progress of disease development increased with increasing the age of the crop in timely to late seeded crop conditions. The AUDPC was also found accelerated with advancement of crop age. The higher value of AUDPC was recorded under late seeded conditions (5 December to 25 December) than timely seeded (15 November).

(ii) Year-wise: The results (Table 2) of simple correlation between the crop age and foliar blight disease intensity and disease development (AUDPC) demonstrated the significant positive correlation at 5 % significance level during all the years. Out of six years, strong positive correlation was exhibited during 1998-99, 1999-00, 2001-02 and 2002-03. Pooled analysis also showed positive correlation for PDI (r=0.80280) and AUDPC (r=0.78849).

(b) Cumulative Degree Days (CDD) with PDI and AUDPC :

Significant positive correlation (p=0.05) of per cent disease intensity and area under disease progress curve was found during all the seeding dates as well as in pooled analysis. The correlation coefficients values of pooled data for the disease intensity and AUDPC are 0.84768 and 0.85718, respectively (Table 3). The value of Cumulative Degree Days was higher under late seeded (5 December to 25 December) than timely seeded conditions (15 November).

(c) Meteorological variables with PDI and AUDPC :

The data regarding correlation analysis of meteorological factors with PDI (Table 4) revealed that maximum, mean, minimum, morning, afternoon temperature and bright sunshine hours exhibited significant (p=0.05) positive correlation during all the years as well as in pooled data. Relative humidity (morning, afternoon and mean) showed significant negative correlation with per cent disease intensity during experimental years except 2000-01 and in pooled data. Similarly, temperatures and sunshine hours have significant positive correlation whereas, relative humidity showed negative correlation with AUDPC (Table 4).

Multiple regressions (R^2):

(a) Year-wise meteorological variables with PDI : The data of meteorological parameters and foliar blight disease intensity was analysed by step-wise multiple regression method to formulate the prediction equation. The year-wise multiple regression equation formulated with various independent variables in relation to foliar blight disease intensity indicated that crop age i.e. days after sowing have showed consistently positive effect for disease intensity during all the six years (Table 5). Temperature factor (like morning, maximum and minimum temperatures) was found as critical. The regression co-efficient (R^2) values were ranging from 0.9720 to 0.9890. On pooled data analysis, crop age and minimum temperature exhibited positive effect whereas, afternoon temperature reflected negative effect for disease intensity with R^2 value of 0.6866.

(b) Seeding date-wise meteorological variables with PDI : To confirm the responsible factors according to seeding date, the data of meteorological parameters and disease intensity was analysed by step-wise multiple regression method (Table 6). The crop age exhibited consistently positive effect in different seeding dates whereas, afternoon temperature had negative effect on disease intensity. The regression co-efficient values were ranging from 0.7430 to 0.8926.

(c) Year-wise meteorological variables with AUDPC : The year-wise multiple regression equations for AUDPC are presented in Table 7. The crop age factor was found most crucial as it had significant positive effect on disease progression during all the years and in pooled data. The morning temperature showed positive effect whereas, afternoon temperature exhibited negative effect. The regression co-efficient values were ranged from 0.9386 to 0.9954 and 0.6764 during the years and in pooled analysis, respectively.

(d) Seeding date-wise crop age and CDD with PDI : The regression equation for per cent disease intensity with crop age and cumulative degree days revealed that two crucial factors viz., crop age and CDD showed positive effect with R^2 values of 0.8322 to 0.8591 during timely to late seeding conditions (Table 8).

(e) Seeding date-wise crop age and CDD with AUDPC : The regression equation for AUDPC with crop age and cumulative degree days, reflected that both, crop age and growing degree days had exhibited positive effect on disease progression. The R^2 value ranged from 0.7824 to 0.8601 during timely to late seeding conditions (Table 9).

Comparison

Growing degree days during the years of disease appearance and disease non-appearance for the period of 41-50 DAS and 51-60 DAS as analysed on the frequency base analysis (Table 10) revealed that degree days 65 to 95 during 41-50 DAS and 51-60 DAS were found critical for the disease development. The respective frequency percentage of 65 to 95 degree days were 63.33 and 66.67 for 41-50 DAS and 51-60 DAS during the years of disease appearance, whereas, same were comparatively less (40.0 and 36.85 %) during the years of disease non-appearance. The data further elucidated that morning and afternoon temperatures for the period of 31-40 to 51-60 DAS in timely sown conditions during the years of disease appearance and non-appearance clearly reflected the important role of temperature in foliar blight disease development.

Prediction Equation

In the current study, the prediction equations were formed based on significant biological and meteorological parameters to predict foliar blight disease under natural conditions. The independent variables *viz*. crop age (i.e. DAS) and temperatures (minimum, maximum, mean, morning and afternoon) were utilized to develop the model for disease forecast. In various analyses, temperature exhibited significant role in disease development, therefore, thermal time (degree days) is preferred to use with crop age for the prediction equation rather than maximum, minimum, morning and afternoon temperatures as it is easy to calculate and required only easily available maximum and minimum temperature values.

Prediction equation based on pooled analyses with crop age (i.e. DAS) and CDD revealed that an increase of one unit in independent variable like DAS and cumulative degree days resulted in increase of foliar blight intensity and AUDPC to the tune of 0.73 and 0.08 per cent and 4.46 and 0.64 per cent, respectively.

PDI = -25.7544 + 0.7298 DAS + 0.0878 CDD (R^2=0.7709)

AUDPC = -196.2409 + 4.4636 DAS + 0.6421 CDD (R^2 = 0.7779)

Epidemiological studies in South Asia suggested that *C. sativus* dominates when the weather warms up toward the end of the wheat season (Dubin and Bimb, 1994). Aerial dispersal of *C. sativus* dominated later in the season, presumably due to the effect of higher temperatures. A relation between foliar blight development, growth stage and temperatures were documented by Bhatta *et al.* (1998). Late seeded (30 December) wheat fields were suffered more from foliar blight than plots seeded on the optimum date (30 November) in eastern India (Singh *et al.*, 1998). Foliar blight development accelerated after flowering (starting from late February until early March) with the advancement of plant growth stage (Duveiller *et al.*, 2003). Higher AUDPC value for late seeding than early seeding was also reported (Duveiller *et al.*, 2005). Singh and Singh (2009) reported significant positive correlation of minimum and maximum temperatures with spot blotch disease of wheat. They further noted that disease intensity was negatively correlated with minimum and maximum relative humidity. The findings of this study are critical for an efficient integrated crop management strategy to manage the foliar blight in warmer wheat growing areas.

CONCLUSION

From the present investigation, it can be concluded that PDI and AUDPC of late seeded crops exhibited significantly strong positive correlation with crop age and were accelerated with advancement of crop age. The meteorological factors *viz.*, minimum, maximum, mean, morning and afternoon temperatures showed significant positive correlation, whereas morning, afternoon and mean relative humidity reflected significantly negative correlation with PDI and AUDPC. The co-efficient of determination (R^2) for the fitted model inclusive of only two factors *viz.*, crop age (i.e. DAS) and cumulative degree days for disease intensity.

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Table 1: Disease development at various growth stages of crop in relation to sowing date

Sowing Date	Per Cent Disease Intensity at DAS					
	31-40 (Vegetative)	**41-50 (Flowering)**	**51-60 (Anthesis)**	**61-70 (Early dough)**	**71-80 (Hard dough)**	**Terminal**
15th November	5.34* (0.63)**	10.53 (4.34)	20.28 (13.97)	32.27 (32.71)	47.45 (57.64)	68.80 (84.00)
25th November	4.91 (0.35)	13.64 (6.02)	24.86 (19.72)	40.45 (43.87)	62.17 (74.56)	75.48 (90.31)
5th December	7.95 (1.93)	23.46 (17.78)	35.88 (35.16)	53.62 (63.69)	67.76 (81.47)	78.14 (93.86)
15th December	11.49 (4.29)	28.00 (24.16)	41.90 (45.22)	62.61 (75.18)	73.68 (90.08)	78.75 (94.30)
25th December	12.07 (16.18)	36.08 (36.34)	56.69 (65.88)	70.70 (86.96)	77.90 (93.35)	78.64 (93.26)
S.Em. ± T	2.24	2.83	3.54	3.78	3.56	2.64
Y X T	0.47	0.67	0.65	0.73	1.98	2.55
C.D. (0.05) T	6.61	8.35	10.45	11.14	10.51	NS
Y X T	1.33	1.88	1.82	2.05	5.57	7.17
C.V. %	9.14	5.98	3.59	2.81	6.01	6.71

** Mean of six years (1998-99 to 2003-04)*
*** Figures in parentheses are re-transformed values*

Table 2: Relationship of crop age with disease intensity (PDI) and AUDPC

Sr. No.	Seeding Date/Year	Correlation Coefficient* "r"	
		PDI	**AUDPC**
1.	**Seeding date-wise**		
	a. 15 November	0.81500	0.79866
	b. 25 November	0.88785	0.88573
	c. 05 December	0.89862	0.85686
	d. 15 December	0.91056	0.92549
	e. 25 December	0.91397	0.85501
2.	**Year-wise**		
	a. 1998-99	0.88539	0.89432
	b. 1999-00	0.90263	0.90144
	c. 2000-01	0.68771	0.69129
	d. 2001-02	0.93416	0.94486
	e. 2002-03	0.92851	0.93278
	f. 2003-04	0.72685	0.65798
	Pooled	0.80280	0.78849

** Values significant at p=0.05*

Table 3: Relationship of cumulative degree days (CDD) with PDI and AUDPC

Seeding Date	Correlation Coefficient* "r"	
	PDI	**AUDPC**
a. 15 November	0.87211	0.88170
b. 25 November	0.86713	0.88062
c. 05 December	0.82001	0.80973
d. 15 December	0.83262	0.85710
e. 25 December	0.90938	0.91756
Pooled	0.84768	0.85718

**** Values significant at p=0.05***

Table 4: Year-wise Correlation coefficient values of meteorological variables with PDI

Parameter	Correlation Coefficient "r"						
	1998-99	**1999-00**	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**Pooled**
Max Temp.	NS	0.40875	0.91501	0.43219	0.68292	0.69888	0.41709
Mini Temp.	0.52654	NS	0.84306	NS	0.60396	NS	0.35373
Mean Temp.	0.41804	0.39060	0.90427	NS	0.76796	0.53634	0.42348
Morn.Temp.	0.59750	NS	0.89808	0.54984	0.50492	0.53979	0.40838
Afternoon T.	0.37848	NS	0.76583	0.39811	0.75928	0.73622	0.27957
Morn.RH	NS	0.55115	0.51136	-0.78447	NS	-0.72264	-0.14055
A.noon RH	-0.35997	0.52606	NS	-0.51248	-0.37235	-0.86363	-0.23896
Mean RH	-0.37236	0.74298	0.46961	-0.81218	NS	-0.83334	-0.22911
Sunshine	NS	NS	0.74269	0.67361	NS	0.86783	0.28490
Critical value (0.05)	± 0.34338	± 0.36034	± 0.39521	± 0.31975	± 0.31558	± 0.36034	± 0.13947

Table 5: Year-wise multiple regression equation (R^2) for PDI

Year	Prediction equation	Regression co-efficient (R^2)
1998-99	$Y = -362.544 + 1.4718 X_1 - 16.1586 X_3 + 24.0697 X_5 + 21.4200 X_{10}$	0.9720
1999-00	$Y = -188.4903 + 1.5538 X_1 + 2.7583 X_9$	0.9749
2000-01	$Y = -320.8143 + 0.7393 X_1 + 11.8966 X_2 + 5.6378 X_5 - 4.2437 X_6$	0.9827
2001-02	$Y = 92.3051 + 1.3327 X_1 - 2.1455 X_9$	0.9769
2002-03	$Y = -332.2737 + 1.2725 X_1 + 8.8747 X_6 + 1.3187 X_8$	0.9804
2003-04	$Y = -3.9343 + 0.6500 X_1 + 5.0017 X_5 - 0.6977 X_7 - 1.0828 X_8 + 4.9782 X_{10}$	0.9890
Pooled	$Y = -92.1601 + 1.5721 X_1 + 3.8326 X_3 - 1.9406 X_6 + 5.6583 X_{10}^{*}$	0.6866

Where,

Y=Predicted PDI; X_1= Days after Sowing; X_2= Maximum temperature; X_3= Minimum temperature; X_5= Morning temperature; X_6= Afternoon temperature; X_7= Morning relative humidity; X_8= Afternoon relative humidity; X_9= Mean relative humidity; X_{10}= Bright sunshine hours; * Non-significant

Table 6: Sowing Date-wise multiple regression equation (R^2) for PDI

Sowing Date	Prediction Equation	Regression Coefficient (R^2)
15th Nov.	$Y = 17.6406 + 1.7235 X_1 - 3.8063 X_6$	0.7430
25th Nov.	$Y = -20.2211 + 2.2470 X_1 + 3.2304 X_3 - 4.3663 X_6$	0.8744
05th Dec.	$Y = -13.3689 + 2.1646 X_1 + 4.2474 X_5 - 4.7384 X_6$	0.8070
15th Dec.	$Y = -29.9926 + 2.1800 X_1 + 0.5804 X_2 - 2.3534 X_6$	0.8738
15th Dec.	$Y = -91.2898 + 2.1213 X_1 + 0.6513 X_9 - 0.4052 X_{10}^{*}$	0.8926

Where,

Y=Predicted PDI; X_1= Days after Sowing; X_2= Maximum temperature; X_3= Minimum temperature; X_5= Morning temperature; X_6= Afternoon temperature; X_9= Mean relative humidity; X_{10}= Bright sunshine hours; * Non-significant

Table 7: Year-wise multiple regression equation (R^2) for AUDPC

Year	Prediction Equation	Regression Coefficient (R^2)
1998-99	$Y= - 3576.7109 + 10.3575 X_1 - 214.3157 X_3 + 263.4428 X_5 + 13.9314 X_7 + 119.5240 X_{10}$	0.9386
1999-00	$Y= -1381.1960 + 10.7191 X_1 + 19.6570 X_9$	0.9772
2000-01	$Y= -1499.7191 + 4.6746 X_1 + 117.1503 X_4 - 32.6075 X_6$	0.9881
2001-02	$Y= 2597.5977 + 9.0561 X_1 - 56.1502 X_2 + 60.2583 X_5 + 27.9984 X_6 – 18.2047 X_9 – 193.1133 X_{10}$	0.9901
2002-03	$Y= -1257.4829 + 8.7161 X_1 + 14.8179 X_5 + 40.8826 X_6 – 39.8296 X_{10}$	0.9816
2003-04	$Y= -348.8991 + 4.0125 X_1 + 44.0503 X_2 + 42.2214 X_4 + 27.8458 X_5 - 63.4444 X_6 – 9.8587 X_7 - 5.5707 X_8 - 68.7066 X_{10}$	0.9954
Pooled	$Y= -676.4743 + 10.5389 X_1 + 27.1781 X_3 - 12.4938 X_6 + 37.6072 X_{10}$	0.6764

Where,

Y=Predicted AUDPC; X_1= Days after Sowing; X_2= Maximum temperature; X_3= Minimum temperature; X_5= Morning temperature; X_6= Afternoon temperature; X_7= Morning relative humidity; X_8= Afternoon relative humidity; X_9= Mean relative humidity; X_{10}= Bright sunshine hours

Table 8: Seeding date-wise regression equation (R^2)of PDI with DAS and CDD

Sowing Date	Prediction Equation	Regression Coefficient (R^2)
15th Nov.	$Y= - 48.7755 + 0.1005 X_1 + 0.88706 X_2$	0.8591
25th Nov.	$Y= -55.4534 + 0.0663 X_1 + 1.2141 X_2$	0.8322
05th Dec.	$Y= -55.3703 + 0.0474 X_1 + 1.4435 X_2$	0.8399
15th Dec.	$Y= -57.5971 + 0.0108 X_1 + 1.7908 X_2$	0.8303
15th Dec.	$Y= -45.7689 + 0.0236 X_1 + 1.6971 X_2$	0.8343

Where,

Y=Predicted PDI; X_1= Days after Sowing; X_2= Cumulative Degree Days

Table 9: Seeding date-wise multiple regression equation (R^2) for AUDPC with DAS and CDD

Sowing Date	Prediction equation	Regression Coefficient (R^2)
15th Nov.	$Y = -341.9853 + 0.7224\ X_1 + 5.3177\ X_2$	0.8578
25th Nov.	$Y = -378.6158 + 0.5074\ X_1 + 7.3909\ X_2$	0.8416
05th Dec.	$Y = -361.4238 + 0.4033\ X_1 + 8.6922\ X_2$	0.7824
15th Dec.	$Y = -425.2347 + 0.1284\ X_1 + 11.7677\ X_2$	0.8601
15th Dec.	$Y = -338.8720 + 0.2151\ X_1 + 10.9765\ X_2$	0.8531

Where,

Y=Predicted AUDPC; X_1= Days after Sowing; X_2= Cumulative Degree Days

Table 10 : Comparison of GDD for the period of disease appearance (1998-99 to 2003-04) and non-appearance (2004-05 to 2006-07)

Sr. No.	Class Limits (Degree Days)	Frequency (%)	
		98-99 to 03-04	**04-05 to 06-07**
41-50 DAS			
1.	50 < 65	6.67	0.00
2.	65 < 80	30.00	16.67
3.	80 < 95	33.33	23.33
4.	95 < 110	20.00	30.22
5.	110 < 125	10.00	08.56
51-60 DAS			
1.	50 < 65	3.33	0.00
2.	65 < 80	26.67	10.53
3.	80 < 95	40.00	26.32
4.	95 < 110	16.67	15.79
5.	110 < 125	10.00	15.79
6.	> 125	3.33	21.05

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